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Lateral closed wedge versus reverse-V osteotomy for cubitus varus: A saw-bone study

Lateral closed wedge versus reverse-V in cubitus varus

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Abstract
Aim: In this study, we aimed to perform a biomechanical comparison of Lateral Closed Wedge (LCW) osteotomy and Reverse-V osteotomy techniques in cubitus varus surgery.
Material and Methods: Thirty-six anatomical humerus models were used. Osteotomy was performed with a 2 mm oscillating cutter motor on the templates prepared as Group 1 (LCW osteotomy) and Group 2 (Reverse-V osteotomy). Fixation was achieved with three crossed Kirschner's wires (K-Wires), two lateral and one medial. The translation was measured using a digital caliper. Models were tested in flexion load, varus load, and valgus load at a speed of 0.5 mm/s and a displacement range of 0-5 mm. Loading (N) and Hardness (N/mm) data were calculated and compared statistically.
Results: Mean translation in Group 1 [T1:7.91±0.65 mm (6.8-9mm)] was higher than that in Group 2 [T2:4.47±0.68 mm (3.5-8mm)] (P<0.001). Flexion load, varus cyclic load, and stiffness in Group 1 were higher than Group 2 (P<0.001). No significant difference between the groups in valgus cyclic load and stiffness was found (P<0.419).
Discussion: It was observed that LCW osteotomy was a more rigid system in varus and flexion compared to the Reverse-V osteotomy technique, but there was no biomechanical difference in valgus.

Keywords
Valgus Cyclic Load, Cubitus Varus Surgery, Varus Cyclic Load

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Introduction

Supracondylar humerus fractures are the most common elbow fractures in childhood [1]. Deformities and movement restrictions may be observed in untreated cases [2]. Cubitus varus is the most common late complication with 3-57% [3,4]. Cubitus varus can cause functional and cosmetic problems in the elbow [5]. In addition, surgery is the treatment option in cases with a higher risk of lateral condyle fracture, triceps tendon and ulnar nerve dislocation, posterolateral rotational instability of the elbow, and delayed ulnar nerve palsy [6,7].

Many osteotomy techniques and fixation methods have been described in the literature for cubitus varus deformity. However, there is no gold standard treatment yet [8]. LCW osteotomy, Medial Open Wedge (MOW) osteotomy, Dome osteotomy, and Step-cut osteotomy are commonly used surgical techniques [9–12]. LCW osteotomy is widely used because of its ease of application. However, increased prominence in the lateral condyle is a common complication in long-term follow-up [13,14]. To reduce these complications, a traditional step-cut osteotomy was defined by De Roza and Graziano [12]. Subsequently, Yun et al. modified the Step-cut osteotomy technique and described the Reverse-V osteotomy technique to provide better fixation and create a medial-lateral wall sufficient to fix the distal fragment [15]. Although there are clinical case series about these osteotomy techniques in the literature, the number of patients is deficient, and studies comparing osteotomy techniques are very few [16].

In this study, the LCW osteotomy technique was used frequently in the literature, and the Reverse-V osteotomy technique, considered more stable in clinical studies, were biomechanically compared.

Material and Methods

The local Clinical Research Ethics Committee approved the study (Approval date and number: 28.01.2021/02). Power analysis was performed using the G*Power (v3.1.9.2) program and the sample size was determined. To achieve 80% power at the α=0.05 level, six subjects were required in each group decided to work. A single orthopedic surgeon performed the entire procedure on each model. Osteotomy models and fixations were performed in the Marmara University Orthopedic Surgery Department. Biomechanical tests were performed in Dokuz Eylül University Biomechanics Laboratory.

Study design and Variables: Two-group comparative biomechanical studies:

LCW osteotomy (Group 1), Reverse-V osteotomy (Group 2). The pediatric humerus sawbones model with the same shape, size, and side was the constant variable in the study. Other constant variables were the applied fixation material and technique. The independent variable is the corrective osteotomy technique and post-fixation durability.

Study materials:

In the study, 36 anatomical humerus models suitable for the pediatric age group were used. Two groups were formed, containing 18 specimens (Sawbones #1052, pediatric humerus 26 cm, Pacific Research, Vashon Is., WA, USA).

Course of the study:

In 36 humerus sawbones models, the entry and exit locations of the lateral and medial fixation K-wires were determined by standardizing in the posterior-anterior (PA) drawing. The anatomical axis line (x) and the widest metaphyseal distance perpendicular to the anatomical axis (y) were determined. The distance from the medial endpoint of the metaphyseal widest distance (y) detected before osteotomy to the medial cortex after osteotomy was determined as the amount of translation. The diagram of the distal humerus LCW osteotomy, the translation measurement and Antero-Posterior (AP) x-ray image after reduction and fixation are given in Figure-1. The diagram of the distal humerus Reverse-V osteotomy, translation measurement and AP x-ray image after reduction and fixation are given in Figure-2.

In both groups, osteotomies were performed using a 2 mm oscillating cutter motor on the templates prepared to achieve 30 degrees of valgization. Following the reduction, the K-wires (Three Straight K-wires, 1.6 mm diameter; TST Medical, Istanbul, Turkey) are placed at the predetermined fixation points as two lateral and one medial to ensure adequate fixation (using a custom-made apparatus to minimize inconsistencies) [3,17]. The distance between the anatomical bone model and the medial cortices of the bone models after fixation was measured using a digital caliper (IP-67, 0.01mm/0.0005", INSIZE, Istanbul), and the Translation (T) amounts were determined as T1 for LCW osteotomy and T2 for Reverse-V osteotomy. Each model was then cut transversely from the fixed point in the mid-diaphysis to isolate the distal humerus. Each sawbones was then embedded in a plastic template containing liquid epoxy resin designed to rigidly hold both proximal and distal parts and allowed to become rigid. Mechanical analysis was carried out by fixing the plastic jar to a cylindrical metal with a mechanical compression system.

Mechanical properties:

Mechanical comparison was performed with a universal measuring machine (Shimadzu Autograph 50 kN; Shimadzu Corp). Models were tested in three cycles. Applying force to only one point of the device was prevented by turning the distal joint interface prepared using epoxy resin to the relevant planes. Six models were used for each sample in bending mechanical loading to the humerus, and the force required to be applied at a speed of 0.5 mm/s and a displacement of 0-5 mm was calculated for each configuration. Force and displacement were measured (precision with an accuracy level of 0,1N and 0,01mm). Hardness was calculated according to the slope of the force-displacement curve of three cycles for flexion-varus-valgus measurements. Microsoft Excel (Microsoft Corp., Redmond, WA) software calculates the hardness value (N/mm).

Statistical analysis

IBM SPSS Statistics 22 (IBM Corp.; Armonk, NY, USA) program was used for statistical analysis. The Mann-Whitney U test was used to determine the difference in displacement applied force and hardness between osteotomy groups. A p-value of <0.05 was considered statistically significant. Deviation data against the load were obtained automatically during loading. Displacement versus load showed a linear behavior.

Results

Flexion-varus-valgus mean bending cyclic load values are

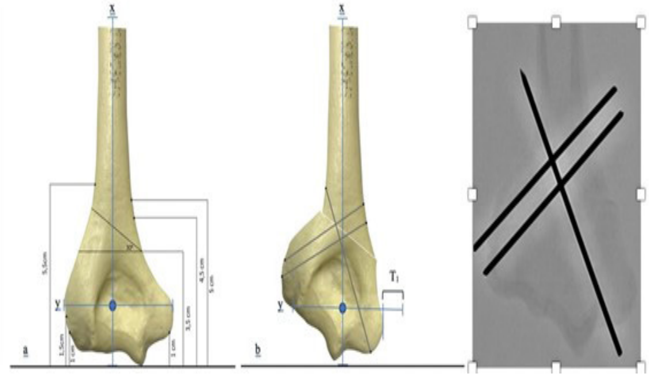

Figure 1. Figure 1 (a, b). Diagram of Distal Humerus Lateral Closed Wedge osteotomy; a- Diagram of fixation sites and osteotomy, b- Diagram of reduction and fixation, determination of the translation amount (T1). c- AP X-ray image of Distal Humerus Lateral Closed Wedge osteotomy after reduction and fixation.

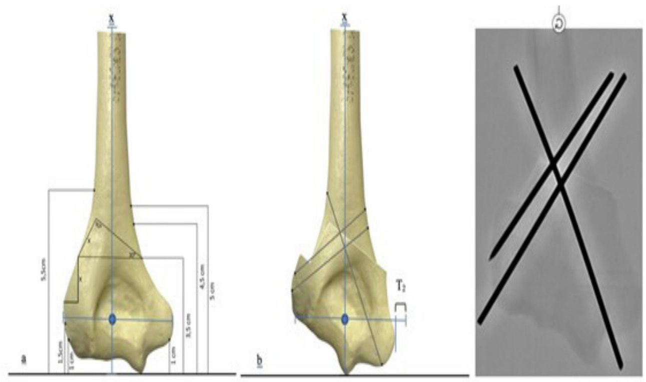

Figure 2. (a, b). Diagram of Distal Humerus reverse-V osteotomy; a- Diagram of fixation sites and osteotomy. b- Diagram of reduction and fixation, determination of the translation amount (T2). c- AP X-ray image of Distal Humerus reverse-V osteotomy after reduction and fixation.

Table 1. Mean bending cyclic load values and standard deviations

	Lateral Closed Wedge Osteotomy (N)	Reverse-V Osteotomy (N)	
Flexion bending (Mean±SD)	14.95±1.99	12.88±0.70	P<0.001
Varus bending (Mean±SD)	37.56±1.27	32.66±1.43	P<0.001
Valgus bending (Mean±SD)	22.65±3.55	20.93±0.80	P<0.419

Table 2. Mean stiffness values and standard deviations against cyclic load

	Lateral Closed Wedge Osteotomy (N/mm)	Reverse-V Osteotomy (N/mm)	
Flexion stiffness (Mean±SD)	3±0.40	2.59±0.14	P<0.001
Varus stiffness (Mean±SD)	7.54±0.26	6.60±0.28	P<0.001
Valgus stiffness (Mean±SD)	4.54±0.70	4.20±0.16	P<0.467

shown in Table-1. Flexion and varus bending cyclic load values were significantly higher in Group 1 compared to Group 2 (P<0.001). There was no significant difference between the groups regarding valgus bending cyclic load values (P<0.419). The mean stiffness values developed against cyclic loading in flexion-varus-valgus bending applied in all osteotomy models are shown in Table-2. The stiffness values developed in flexion and varus bending cyclic loading were significantly higher in Group 1 than Group 2 (P<0.001). There was no significant difference between the groups regarding the stiffness value developed under cyclic loading of valgus bending (P<0.467). The mean translation was T1 7.91±0.65 mm (6.8-9mm) in Group 1 and T2 4.47±0.68 mm (3.5-8mm) in Group 2; the translation was significantly higher in Group 1 than Group 2 (P<0.001). During cyclic loading tests, neither pin loosening nor reduction loss was observed in either group.

Discussion

Contrary to the view in the literature that the Reverse-V osteotomy has a natural stability against varus and valgus forces thanks to the medial and lateral column effect [16], in our study, it was observed that the LCW osteotomy technique was more durable than the Reverse-V osteotomy technique in varus and flexion cyclic loading. No significant difference between the groups in valgus cyclic loading was determined.

Cubitus varus is an elbow deformity that causes biomechanical instability due to medial displacement of the mechanical axis. In LCW osteotomy, one of the classical corrective surgical techniques, angular corrections are calculated by preoperative planning, while the surgeon adjusts mechanical axis correction after osteotomy [13]. In addition, since the classical LCW osteotomy technique does not involve medial translation, it may cause cosmetic problems such as the prominence of the lateral condylar protrusion due to the lateral translation of the distal part [18]. In a Reverse-V osteotomy, which is defined to solve this problem, mechanical axis correction, angle, and placement of the wedge to be removed are calculated with preoperative planning; angular fragments are reduced after osteotomy [16,19]. In addition, lateral condylar prominence is less common than classical LCW osteotomy, since the distal part is technically reduced and translated medially [15]. In our study, osteotomy techniques were used for the standardization of osteotomy lines and angles. The translation amounts of both groups were measured after reduction. As a matter of fact, in our study on model bones, we found that the amount of lateral translation in LCW osteotomy was higher than the amount of lateral translation in Reverse-V osteotomy in the measurements made after osteotomy and reduction procedures. Although technically combining Reverse-V osteotomy with medial translation has advantages, there is a need for biomechanical and clinical studies of different plans. It will cause changes in the biomechanical strength of the models.

Elbow arthrofibrosis is a common complication after elbow osteotomy. Immobilization is the most common cause of elbow arthrofibrosis after cubitus varus surgery. Therefore, stabilization allowing early movement is one of the most critical points for successful functional results in cubitus varus correction surgery [20]. In cases where adequate stabilization is not provided, the prevention of early joint movement to prevent reduction loss adversely affects functional outcome. To address this problem, clinical studies have been conducted on combining osteotomy techniques with different stabilization methods [14,21]. Our study, which is the first experimental study to compare two osteotomy techniques with the same stabilization, found that the LCW osteotomy offers a more rigid fixation than the Reverse-V osteotomy, which emphasizes its natural stability by providing medial and lateral column support. We thought that this might be the difference in the translation amount of the vector distribution. In addition, we predicted that due to the configuration of the Reverse-V osteotomy, the part removed from the distal medial and the cortical surface forces remaining in the proximal medial could change the moment center.

In Cubitus Varus surgery, K-wires, Steinmann pins, screws and cerclage, K-wires supported with tension band, plates, and screws, and external fixators are frequently used as fixation methods after osteotomy [6,14,22]. K-wire fixation is a fixation tool that is easy to use in children with open physis and can be easily removed after union [17]. In the literature, it has been shown that two lateral and one medial K-wires are more rigid than other systems in patients with supracondylar fracture model [3,17,23]. Studies investigating the effect of wire diameter (1.6 mm vs. 2.8 mm) have shown that the resistance of thick K-wire is higher. On the other hand, it is emphasized that 2.8 mm wires are not clinically relevant due to the occasional use of wires over 1.6 mm and 2.0 mm in this age group [24]. We used three smooth K-wires of 1.6 mm in a cross configuration, two lateral and one medial in line with this information. Sufficient stability was achieved with this fixation method, and no reduction loss of pin loosening was observed under cyclic loads in either group.

Sawbones is frequently used in biomechanical studies investigating the effect of wire configuration on strength in supracondylar fixation. Studies using cadavers rather than model bones are rare. Adult cadaver bone was used in these studies because of the difficulty in obtaining pediatric age cadavers [25]. We also preferred to use pediatric humerus sawbones modeling in our study.

There are several limitations to our study. The anatomical model bone used in our study is not a deformity model in which osteotomy is defined may be insufficient to imitate biomechanics. In addition, it does not fully represent pediatric bone, as it does not take into account the peripheral anatomical structures that may contribute to fracture stability, such as the periosteum. In addition, the stress mechanisms applied in our study do not accurately reflect all the physiological stresses experienced by the elbow during recovery. However, the main benefit of using synthetic models is that they allow the isolation of the tested variables as they are uniform structures. In the comparison of osteotomy techniques and biomechanics, there are differences in surgical approaches, ease of application, wound healing, surgical time, and fixation difficulty. A clinical study evaluating all these would contribute significantly to the literature. Future research should focus on biomechanical studies on bone models in which the deformity is mimicked and on further clinical studies that also evaluate other factors.

Conclusion

It was determined that lateral translation was higher after reduction in the classical LCW osteotomy technique than the Reverse-V osteotomy technique. The LCW technique was more stable biomechanically in our sawbones model.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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